Investigating factors which affect heat loss from a beaker of hot water

Planning

In this investigation I am going to survey the factors that affect heat loss from a beaker filled with 55ml of hot water. This will be done by using a numerous amount of materials.

Factors which affect heat loss from a beaker of hot water:

- Mass of H_2O
- Size of beaker
- Temperature Difference
- Material Colour
- Air Pressure
- Relative Humidity

} Evaporation

Forms of heat loss:

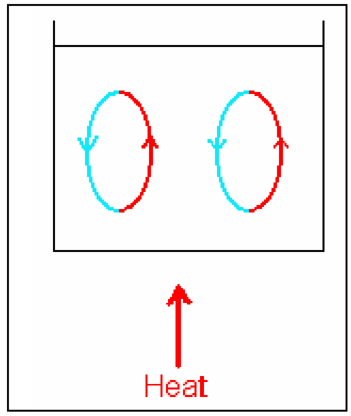
Radiation

This is the loss of energy, in this case heat energy, through the atmosphere via electromagnetic waves. (This gives it the ability to travel through a vacuum, i.e. the sun shining through space to Earth.) When this energy reaches an object it is absorbed by it. The energy absorbed causes particles in the object to vibrate, and so it heats up. The hotter an object is, the more energy it has and therefore more radiation will occur. Also the larger the surface area of an object, the more energy it will radiate. Dull coloured objects radiate more energy than shiny objects.

Convection

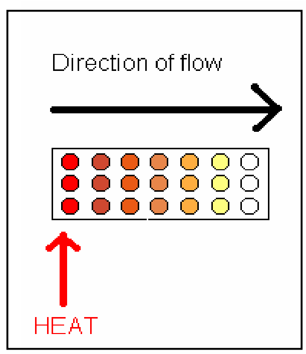
Convection is the expansion of particles when they are heated. When a water is heated, the particles within the substance expand and become less dense that normal.

Due to this decrease in density the particles rise through the substance, and at the surface of the water some of the particles evaporate. As more water evaporates, more and more energy is lost and so the water cools down and when evaporation occurs the object that the substance is evaporating off cools. (This is shown well when you get out the shower and you feel cold because the water is evaporating off of you). When the particles move away from the heat source or are so expanded that the particles are not passing heat from one to another, the particles cool. When they cool they compress back to their original density, which causes them to fall to the bottom of the water. As they are now tightly packed they heat is conducted from one particle to another and they heat, expand, rise, cool and so on as the cycle continues. This cycle is called convection current..

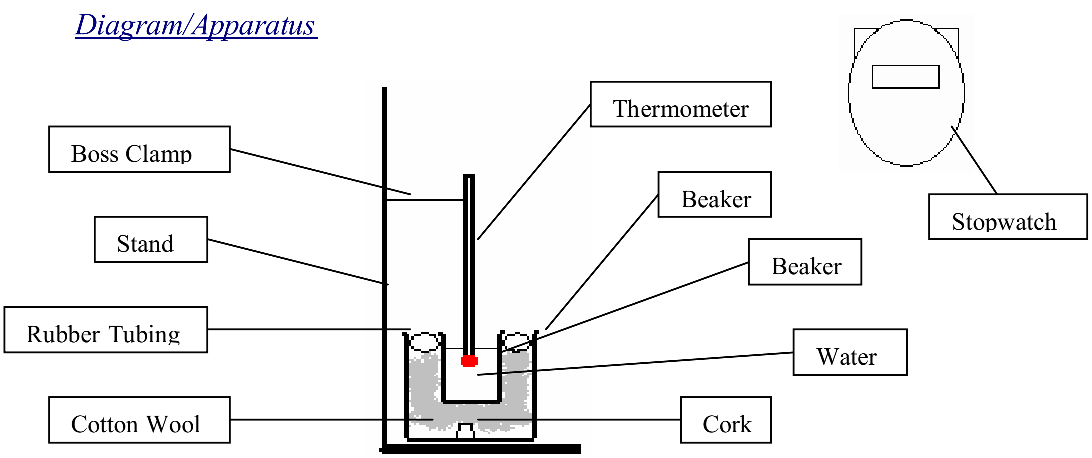


Conduction

Conduction can take place in solids, liquids and gases. When a material is heated the particles nearest to the heat gain kinetic energy. They then start to vibrate faster due to this energy and as they do they touch other particles and transfer the kinetic energy to them. This process is repeated and the energy is transferred through out the object from hot regions to cooler regions. As the water looses heat from the sides of the beaker, conduction will cool the mass of the water. Conduction will also occur through the sides of the beaker and then radiate and through the base.



Diagram/Apparatus



Method

- Collected and set up apparatus.
- Filled beaker with hot water
- Placed beaker on a table and timed for 600s whilst taking down results every 20s. These results were used as a control.
- Then filled up beaker again with hot water.
- Placed beaker carefully in large beaker
- Recorded starting temperature and then timed for 600s taking down results every 20s.
- This process was repeated 3 more times with varied materials.

Prediction

I predict that heat will be mostly lost through convection. This is because as hot water rises to the top it will evaporate and therefore heat will be given off. I believe that conduction will be second most deadly to heat loss, as heat will escape through the sides of the beaker and then escape out of the gaps of the large beaker or again through the sides. Radiation will be the least effective to heat loss, as foil will be wrapped around the beaker. This is because dull objects radiate more energy than shiny.

I think heat loss will be most effective when no foil is wrapped around the large beaker and when there is no insulation between it because then conduction and convection take their role therefore losing the most heat. Whereas I think heat loss will be least effective when there is foil wrapped around the large beaker and when there is insulation in-between. This is because convection is the only form of heat loss that can take place without struggle therefore losing the least heat.

Obtaining Evidence

The following factors will be considered when providing a fair test:

- The starting temperature is the same
- The thermometer is no touching the beaker sides
- The foil is wrapped fully round
- The same volume of water is used (55ml)
- The readings and timings should be constant

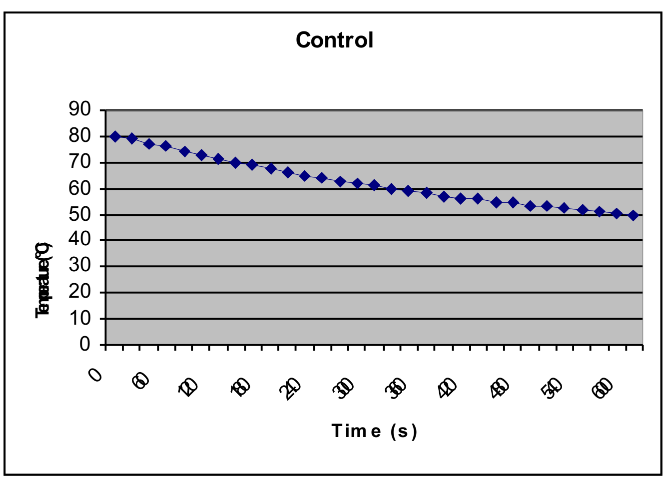
The following factors will be considered when providing a safe test:

- Standing up so if water spills we can move quickly
- No running
- Pour water carefully
- Let beaker cool down

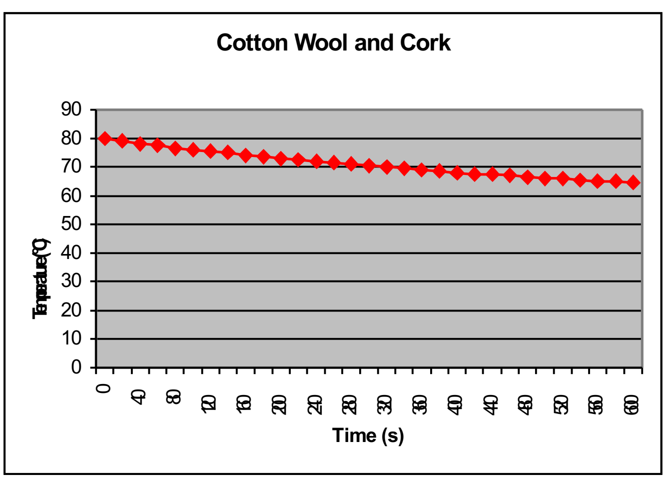
Results

We first had to take a control so that we could compare it to the other results i.e. leaving the beaker by itself on a bench for 600s.

Time/s	Temperature/°C
0	80
20	79
40	77
60	76
80	74
100	73
120	71
140	70
160	69
180	68
200	66
220	65
240	64
260	63
280	62
300	61
320	60
340	59
360	58
380	57
400	56.5
420	56
440	55
460	54.5
480	53.5
500	53
520	52.5
540	51.5
560	51
580	50.5
600	50



Time/s	Temperature/°C
0	80
20	79
40	78
60	77.5
80	76.5
100	76
120	75.5
140	75
160	74
180	73.5
200	73
220	72.5
240	72
260	71.5
280	71
300	70.5
320	70
340	69.5
360	69
380	68.5
400	68
420	67.5
440	67.5
460	67
480	66.5
500	66
520	66
540	65.5
560	65
580	65
600	64.5



Time/s	Temperature/°C
0	80
20	78
40	77
60	76
80	74.5
100	73.5
120	72.5
140	71.5
160	71
180	70
200	69
220	68.5
240	67.5
260	67
280	66
300	65.5
320	65
340	64
360	63.5
380	63
400	62.5
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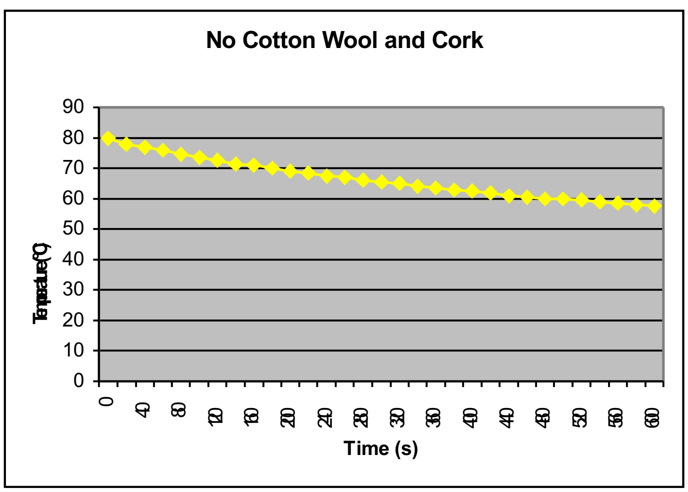
460	60.5
480	60
500	60
520	59.5
540	59
560	58.5
580	58
600	57.5



Time/s	Temperature/°C
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120	77
140	76.5
160	76
180	75.5
200	75
220	74.5
240	74
260	74
280	73.5
300	73
320	72.5
340	72
360	72
380	71.5
400	71
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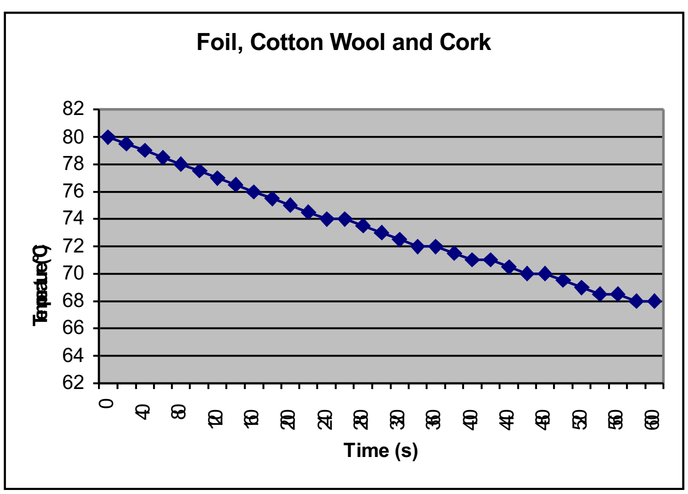
460	70
480	70
500	69.5
520	69
540	68.5
560	68.5
580	68
600	68



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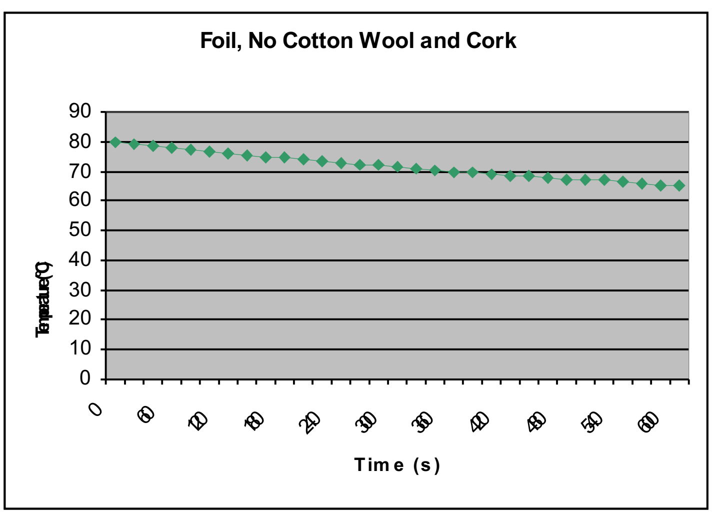

Analysing Evidence and Concluding

By using the control you can compare it to the other results and you can see that by using insulation and double glazing heat loss can be prevented. The control finished ate 50°C. The heat was lost to the surroundings including the bench through conduction.

1st Experiment: Cotton Wool and Cork

Once the experiment started you could already see after 1 minute that the insulation was helping to prevent heat loss. This is because after a minute it was 77.5°C and the control after a minute was 76°C so there was a 1.5°C difference in temperature. After 10 minutes the end temperature was 64.5°C. This makes a 14.5°C difference between the control.

2nd Experiment: No cotton wool and Cork

This experiment was very slow starting and was losing lots of heat during the beginning but as time passed the heat loss reduced. The final temperature was 57.5°C after 10 minutes. This makes a 7.5°C difference between the control. This shows us that the double glazing does prevent heat loss.

3rd Experiment: Foil, Cotton Wool and Cork

This experiment had the most insulation. After 1 minute it was 78.5°C which meant it had only dropped 1.5°C. The final temperature was 68°C after 10 minutes. This gave it a huge 18°C difference between the control.

4th Experiment: Foil, No Cotton Wool and Cork

This experiment was constant and decreased in temperature at a steady rate. The final temperature was 65°C after 10 minutes. This made a 15°C difference between the control. Foil prevented heat loss dramatically.

Evaluating

Looking at all the experiments we can now determine which materials were best at preventing heat loss. Here is a table with the statistics of how much heat was lost (all these experiments had double glazing):

Cotton Wool and Cork: 15.5°C
No Cotton Wool and Cork: 22.5°C
Foil, Cotton Wool and Cork: 12°C
Foil, No Cotton Wool and Cork: 15°C

After looking at this table you can see that the most conserved single material was foil as it prevented the most heat from going through. I no this because even when there was no cotton wool and cork it still came second in preventing heat loss. This proves that shiny objects radiate a little amount of energy. Although foil prevented the most heat loss cotton wool and cork still prevented conduction by having cotton wool between both beakers and by placing a cork underneath the beaker.

This means that foil would have a lower U-Value than the other materials because it is a better insulator.

After completing all the experiments I can say my prediction was correct. This is because the 3rd experiment finished on 68°C meaning it only lost 12°C in 10 minutes. All the other experiments had lost the more heat meaning this one had the most insulation. I also predicted that the 2nd experiment would lose the most heat. This was correct again as it had the least insulation except for double glazing which still prevented 7.5°C.

Anomalies

- We should have recorded the room temperature before and after to see if it had an effect on the results.
- Should have closed all windows to make sure that no drafts came in.
- The cork was not always up right.

Improvements

There are many ways we could have improved the experiment. Here are a few:

- Tested out more materials i.e. black card and foam.
- Made the experiment longer
- Use lid for the beaker to stop evaporation occurring
- Use more beakers

We could also repeat the experiment again but take it further and calculate U-Values which then would have enabled us to calculate heat energy lost per second using this equation:

Heat energy lost per second = U-value (W/m^2°C) x area (m^2) x △ T (°C)